Progress Report

Grant #731009
Ultra-Efficient Generators & Diesel Electric Propulsion
Genesis Machining & Fabrication
Reporting Dates: 4/2014-6/2014

Deliverables Submitted:

Budget:

We are invoicing for $8,750 for labor, $33,323.57 for materials, equipment and other expenses. We are requesting $48,430 in advance for labor and materials during the July - September quarter of 2014. Finally, we are submitting $26,168.56 in match.

Schedule Status:

We continue to be a little behind schedule because of the long lead time for our bus-scale diesel power unit. However, we continue to work on the TRL-7 design and have had plenty to do. Also, we are not as far along with PCB design as we would like because of delays in acquiring the design software.

Work Progress:

AEA / ACEP Site Visit – Tom Johnson, Alan Baldivieso, and Jason Myer.

1. Engine for Bus Scale Genset

We upgraded to a 275 HP (205 kW) engine as it was only slightly more expensive. The engine is currently being assembled and will ship within the July to September reporting period. We have begun paying Cummins for the engine.

2. Heatsink Validation

During this quarter we have yet again revised our heatsink design and validated the new design. Following the AEA / ACEP visit we completed the assembly and calibration of our calorimetric heatsink test-stand. Using this setup, we evaluated the SnPlus thermal interface material from Indium Corp. and found its performance to be inadequate. We then redesigned our heatsink and thermal interface material and tested this new design. Its performance far exceeded the first test and gives us a high degree of confidence that it will perform to full power in the TRL-7 design.

Experimental Setup:

Our heatsink evaluation was performed using a current source to drive current through the freewheeling diode of four IGBT’s in series mounted on a heat exchanger. Each IGBT had its own internal thermistor bonded to its die. An inlet and an outlet thermistor were installed on the heat exchanger, and a turbine flow meter was also installed. Thermistors were calibrated by bringing the test rig to thermal equilibrium at three different temperatures. Calibration values were used to calculate parameters of the Steinhart-Hart equation to linearize each thermistor. Frequency data from the turbine flow meter was calibrated by filling a known volume at five different flow rates. The fill time was then used to generate points for a third-order polynomial interpolation algorithm. Flow and temperature information was used to calculate real-time power values. Data was collected using a National Instruments 9609 FPGA board and data acquisition mezzanine card.

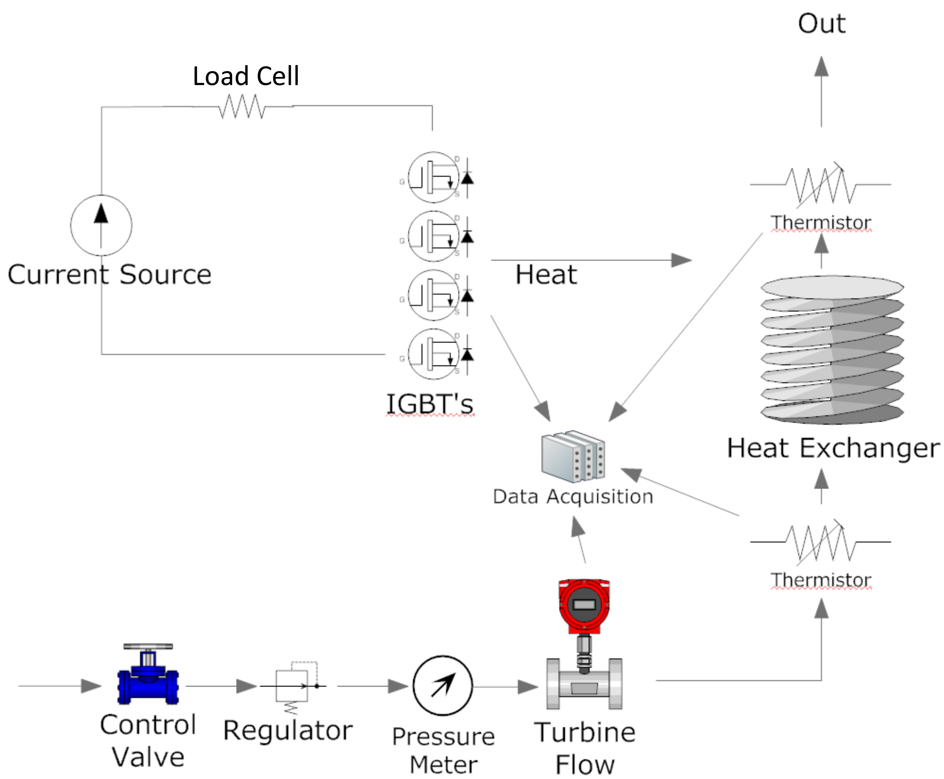
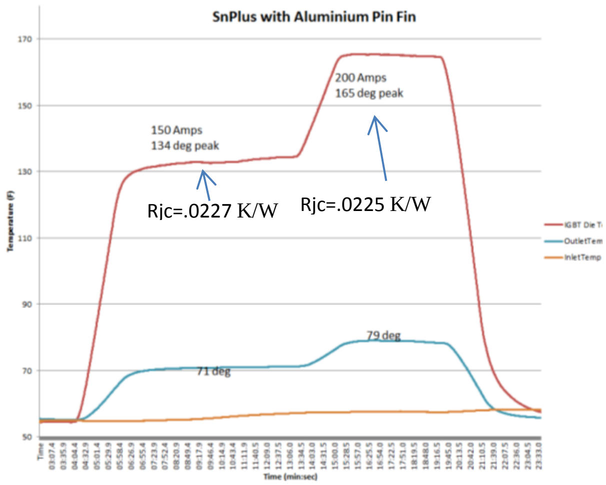
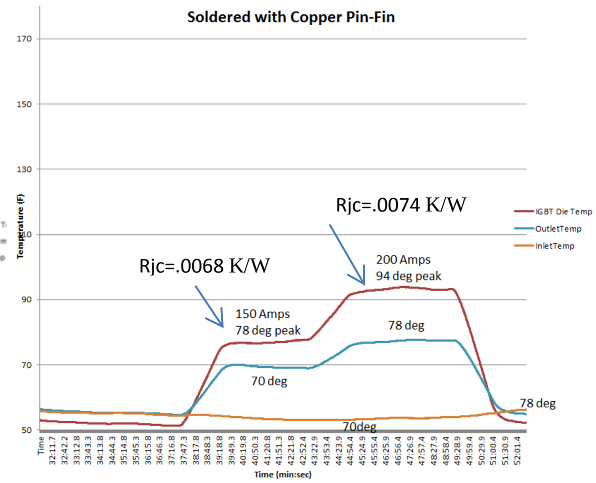
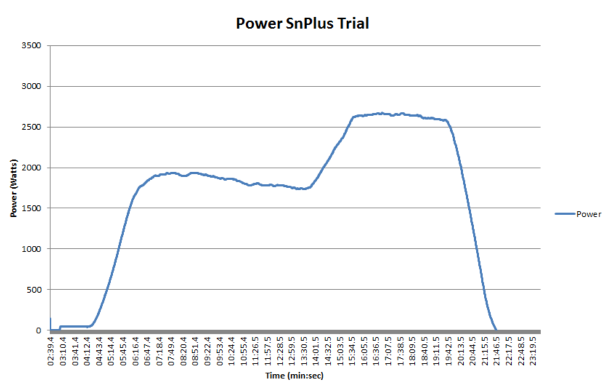


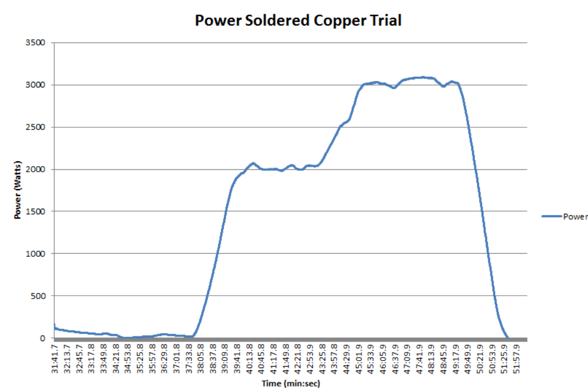
Figure 1 - Experimental Setup

Data from the SnPlus trial is shown side-by-side with our revised heatsink design. The heatsink was rebuilt by making copper pin-fin inserts and directly soldering the copper IGBT baseplate to the heatsink. Data presented from each trial shows the second best performing IGBT, as there was a performance span. The flow rate and current level was manually adjusted to be approximately equal for each trial. Ideally, this would result in equal power levels. For these two trials, however, the power was 420 Watts greater for the Copper Pin-Fin trial.

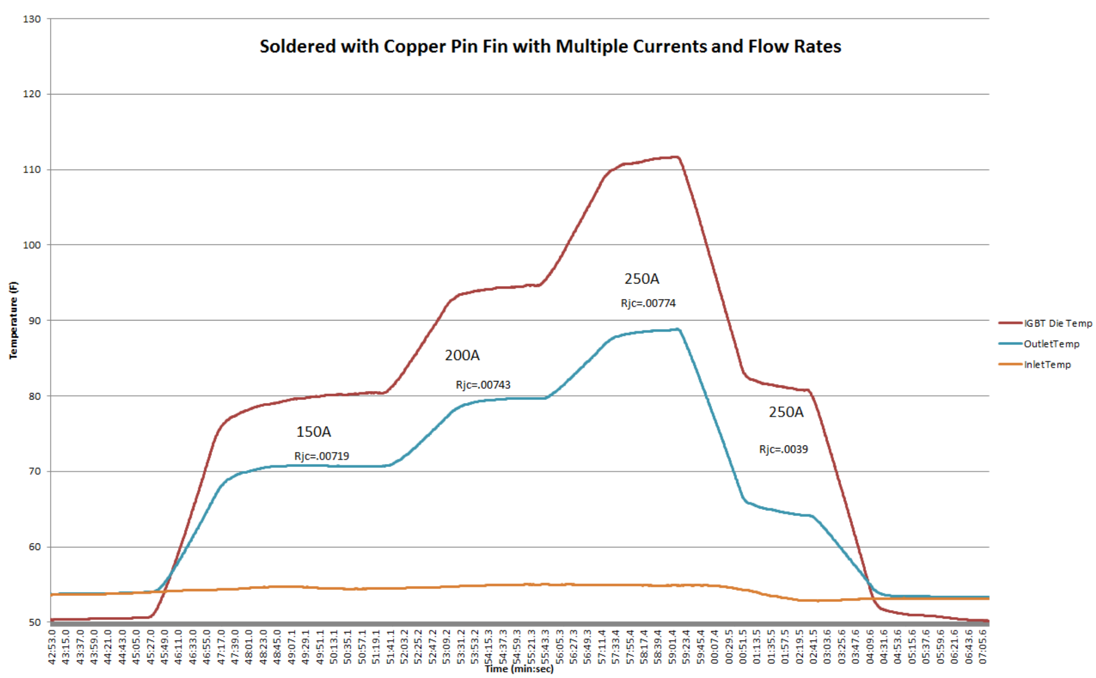








A third trial was performed to observe the effect of increasing the coolant flow rate. Increasing the flow-rate from .05 l/s to around .1 l/s caused the thermal resistance to drop from .00774 K/W to .00388 K/W. The design goal for the heatsink is to dissipate up to 15 kW (3.75 kW / IGBT). With an Rjc of .0039, and water coolant at 50°F, the die temp at full power would be 70°C – far lower than the absolute maximum rating of 275°C. This will leave ample room for higher ambient temperatures and oil based coolants which have a lower thermal conductivity and specific heat.



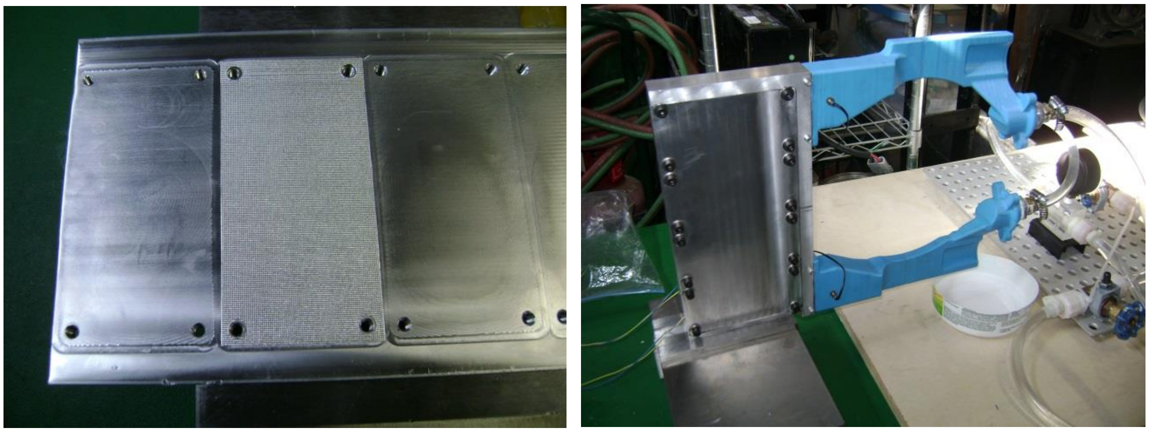


Figure 2 - SnPlus Material (left) Heatsink on Test Stand (right)

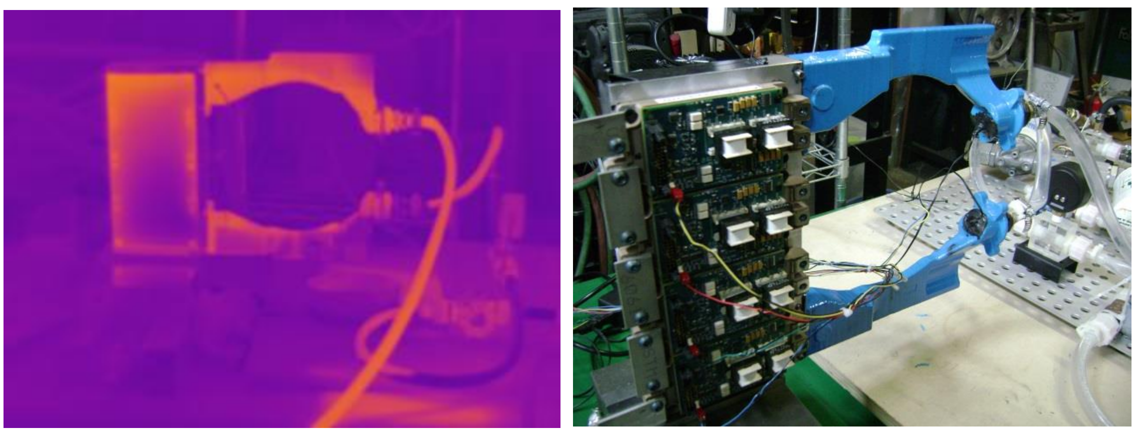


Figure 3 - Infrared image of heatsink in hot to cold transition (left) Test stand with IGBT's mounted (right)

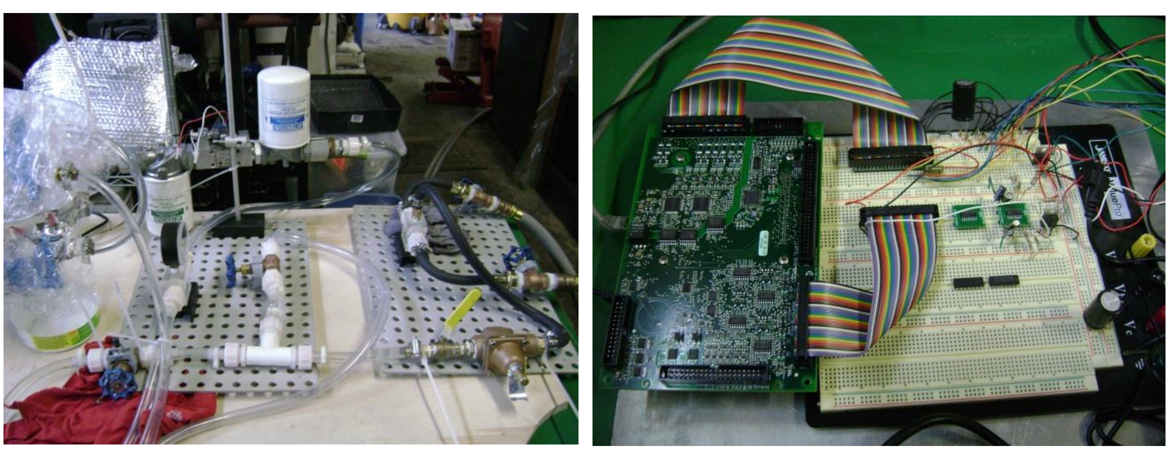


Figure 4 - Fluid control setup with flow meter (left) Data acquisition hardware (right)

Figure 5 - Milling the heatsink insert blanks from copper square-stock (left) Cutting diamond fins (right)

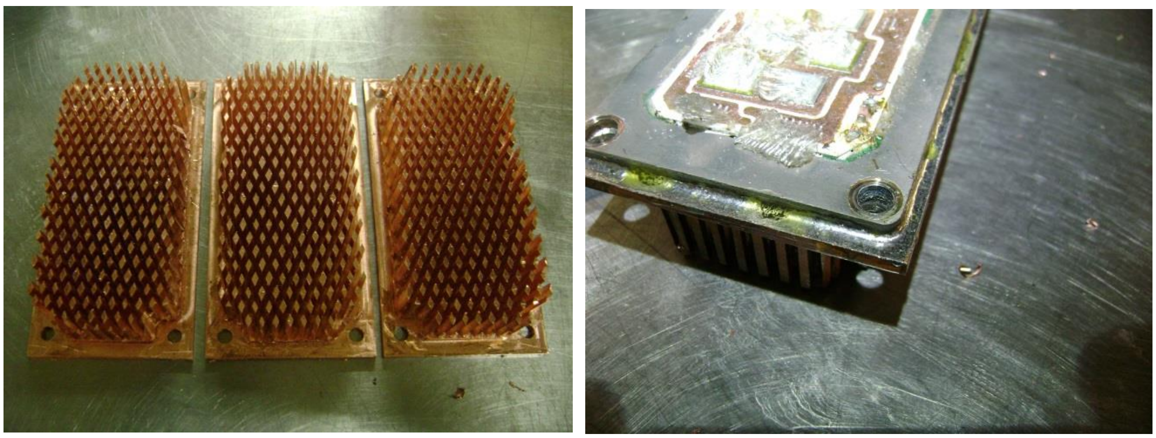


Figure 6 - Diamond pin-fins (left) IGBT module soldered to heatsink (right)

3. TRL-7 Progress

Design work for the TRL-7 inverter modules continues to focus on PCB design. Early in the quarter we discovered the inadequacy of the PCB design package we were planning on using and realized that we needed to migrate to a higher performance package. After evaluating several tools, Altium Designer stood out as being capable of meeting our design criteria including high-speed signaling and integration with mechanical CAD programs. We approached Altium for sponsorship and they paid us a visit in March. Though it took some time to finally get our license in hand, we now own a seat of the Altium package and were able to acquire it at discount. We have continued designing our TRL-7 boards with this powerful package.

Figure 7 - Altium's Ben Jordan and Robert Poll stand with KeV's Seraphim McGann atop Pillar Mountain

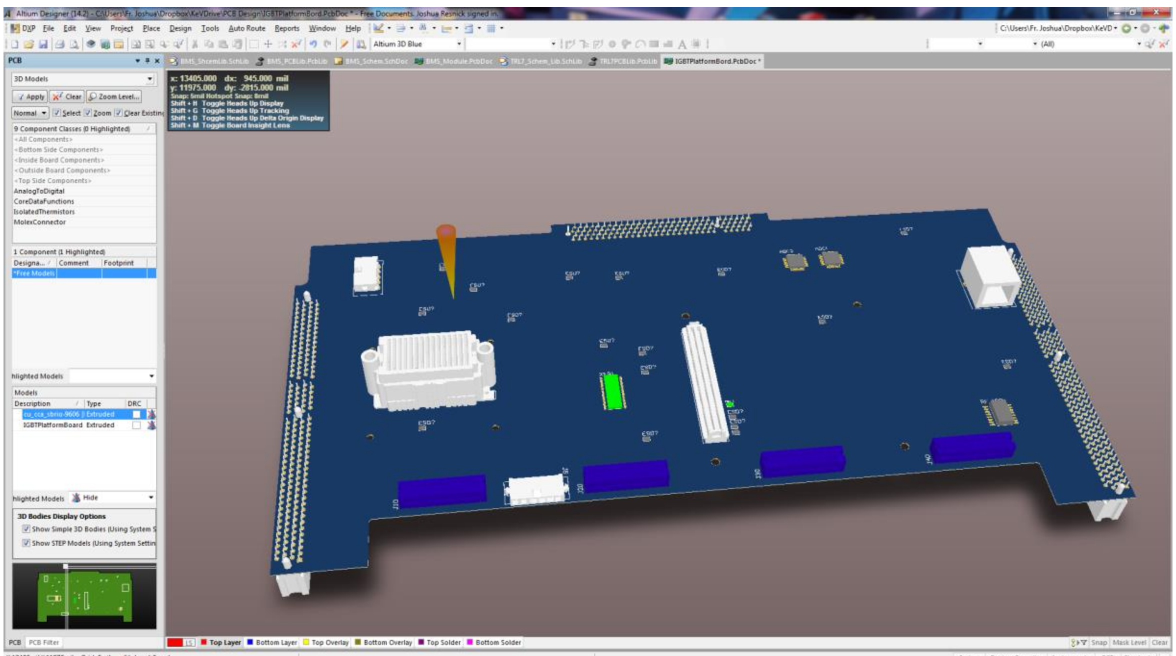


Figure 8 - Screenshot of TRL-7 main board in Altium Designer

Another PCB that we have begun design work on is a Battery Management System. Currently the battery pack on our EV is unmanaged and requires seasonal balancing. Battery management is a critical feature of lithium battery energy storage systems and our new PCB tools will allow us to produce one very easily and at low cost. We hope to build and install our BMS in the EV test bed and in the diesel electric bus.

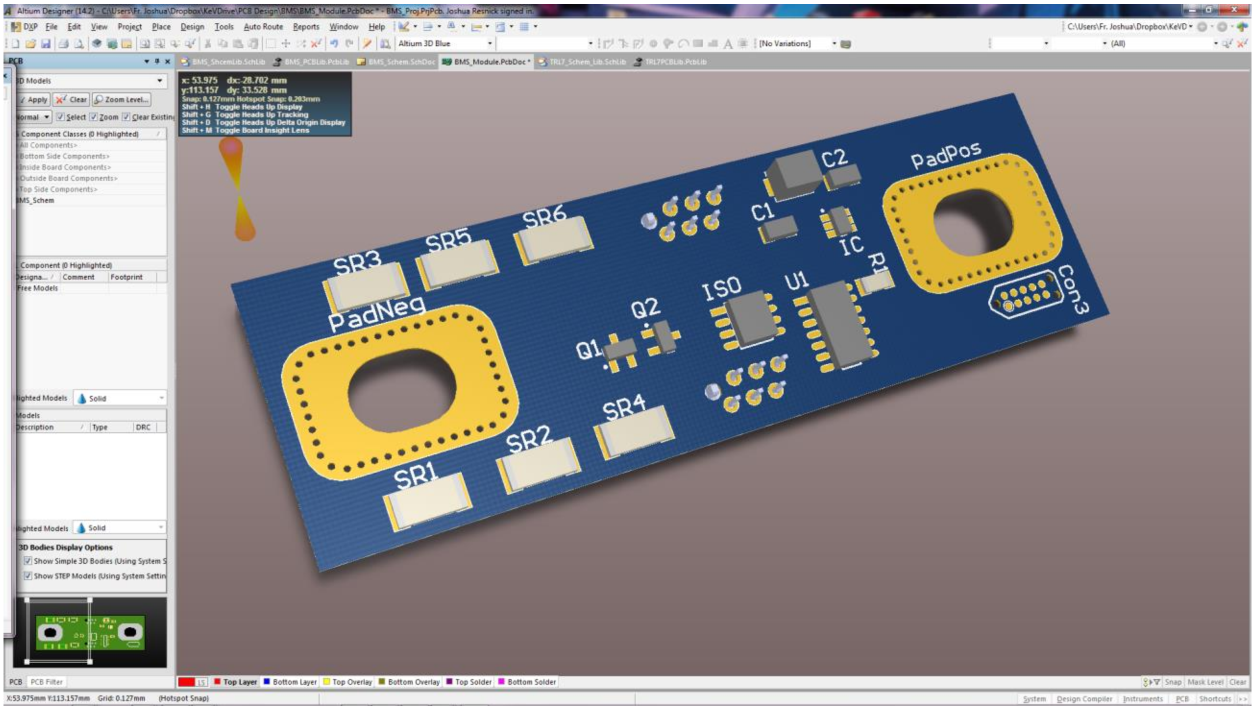


Figure 9 - Battery Management PCB in Altium

4. Pick-and-Place Machine

A significant assembly challenge for our TRL-7 design is the assembly of the printed circuit boards. While low cost printing houses exist for low volume production, it is very expensive to actually place and solder the small, surface mount devices (SMD's) in prototype volumes. In fact, assembling a single prototype board can cost up to $1k because of the setup time. This is a dangerous proposition if revisions are needed. Hand placing the boards is also very risky because they have hundreds of SMD's, some of which are extremely fine-pitched. Faced with this dilemma, we investigated the possibility of buying our own pick-and-place machine. We were very fortunate to find a used machine for around $5k. This low-hours machine was originally $15K! It can place around 2k components per hour and uses a machine vision system to center components.

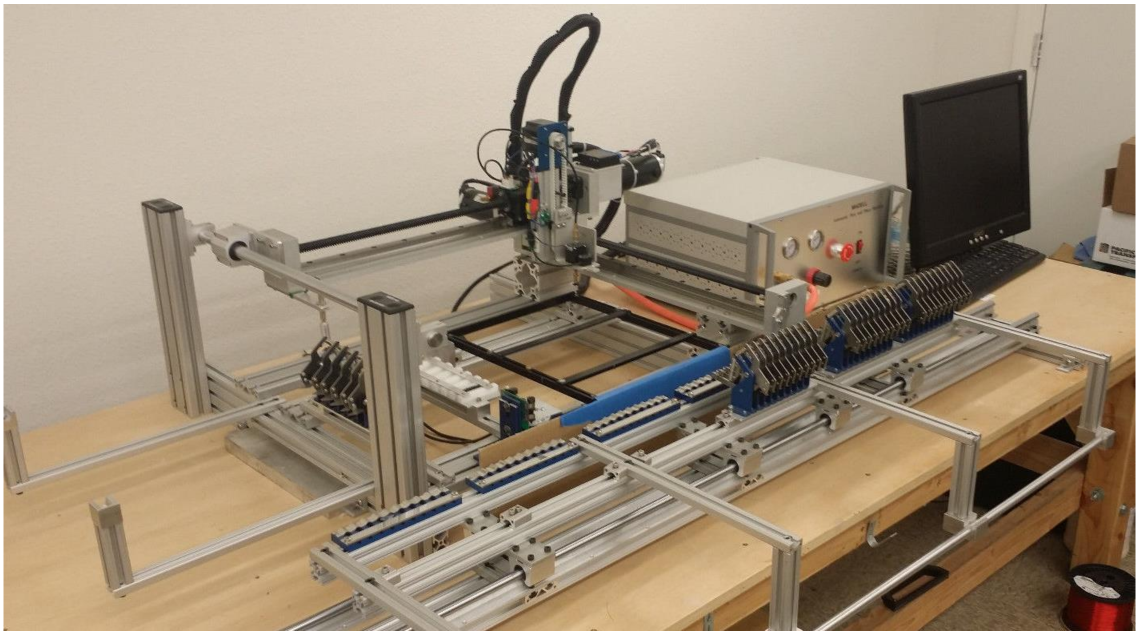


Figure 10 - Our Pick-and-Place Machine

Here is a video of a similar model in action:

http://www.youtube.com/watch?v=OU-EJStWjkM

This is another situation where purchasing a tool is less expensive than the outsourcing costs for prototype volumes. Having our own PNP machine will not only save us money but spare the aggravation of long wait times for prototypes.

In addition to the PNP machine, we also purchased a low cost SMD reflow oven for soldering the components and a manual SMD solder stencil printer. These items will allow us to assemble our own prototype boards and build low volume runs in the future.

5. Generator Head and Propulsion Motor

Both the generator head and the propulsion motor for our DE bus conversion have been purchased. We were able to obtain these identical, brand new units at-cost with a generous contribution from United Electric Motors in Anchorage. The motors have a nameplate power of 50 HP, which will easily accommodate the 275 HP of our power unit once converted for high power density operation.

Figure 11 - 50 HP Generator Head and Propulsion Induction Motor

Work for Next Quarter

1) Design, print, and test TRL-7 PCB designs.
2) Order all parts for TRL-7 inverter modules.